SOIL CHARACTERISTICS OF FIVE TRIAL FIELDS DETERMINED IN THE FRAMEWORK OF THE CROP GROWTH MODELLING PROJECT 07REU07

Marinus BROUWERS
CIRAD, Research Unit 'Annual cropping systems',
Montpellier-France, December 2008

Visiting scientist at SASRI, Resource Optimisation program,
Soil and crop nutrition section, July 2006 – July 2008

CONTENTS:

SOIL CHARACTERISTICS OF FIVE TRIAL FIELDS DETERMINED IN THE FRAMEWORK OF THE CROP GROWTH MODELLING PROJECT 07REU07

Marinus BROUWERS
CIRAD, Research Unit 'Annual cropping systems',
Montpellier-France, December 2008

1 - BACKGROUND

In several growth studies, well-irrigated crops started in spring grow rapidly and achieve high biomass, stalk and sucrose yields in winter, but then exhibit slow growth in the following spring and summer when conditions are favourable for growth. Reasons for this are not clear. The general goal of the 07REU07 project is to gain a better understanding of the processes that that lead to intra-seasonal patterns of biomass accumulation and partitioning.

Incorrect soil data used in the canegro model possibly being one of the factors explaining a part of the observed intra-seasonal patterns, a better characterisation the soils of field trials used for calibration of the canegro model could lead to improved performance of this or other simulation models.
In order to be able to publish the obtained results also in international journals, the soils of trial fields considered in the framework of the project should be named according also to international soil taxonomy systems.

2 – MATERIALS AND METHODS

2.1 Considered fields

The soils of five fields used in the past for calibration of the canegro model were characterised: Two fields of the experimental station of Mount Edgecombe (respectively field number 23 and 41), one of SASRI's Bruynshill farm in the Midlands (field 6A), another at its farm near Pongola (field 316) as well as the field 13221 (previously 200) near Verulam of Hulett's La Mercy farm
Site and soil pit description of these five fields are given in annex 1. They cover a wide range of bedrock, soils and climate but any of them is sandy. In annex 2 are given data on the substratum on which are developed the soils.

2.2 Data requested for growth similation models

Idealy, growth similation models request for as deep as sugarcane roots can grow for each soil layer (measured in cm), at least:

** Soil physical data*

* Drained upper limit (i.e. Field Capacity) - cm^3/ cm^3
* Lower limit (i.e. moisture content at Permanent Wilting Point) - cm^3/ cm^3
* Water-holding capacity (i.e. difference between upper and lower limit) - cm^3/ cm^3
* Saturated water holding capacity - cm^3/ cm^3
* Bulk density[1] - g/cm^3
* Saturated hydraulic conductivity[2] - cm/hour

** Soil chemical data*

* Soil organic carbon
* pH
* Cation exchange capacity (cmol/kg)

[1] for conversion in volumetric units of characteristics measured in % of weight of dry soil
[2] per layer, or a single value for the whole profile

And as other data:
* Root growth factor[3]
* Runoff curve number
* Albedo

Between all these factors, the soil physical data and the maximum rooting depth are essential for the water balance component in growth simulation models.

2.3 Data acquisition methods

As first step, site selection for soil pit description, soil sampling and *in situ* measurements (done between end Mai and the 10th of July 2008) were done in each of the five fields on such way that the selected site can be considered as representative for the uppermost part of each field. The site selection was done on the basis of the land form characteristics of the field, its soil surface state features and augerings done in corners and central part of the fields.

One site was selected for soil pit description, soil sampling and in situ measurements in each field, except in field 23 of Mount Edgecombe where two sites had to be chosen, the most northern part of this field being underlain by a different soil type than its central and southern part.

At each selected site (located with a GPS), a deep soil pit was dug and descript. Bulk samples as well as ring samples were taken of the major soil horizons of each pit (i.e. 3 to 5 levels per pit). Ring samples of 250 cm^3 were taken vertically taken in duplicate for measurement of the bulk density. On the same way, three ring samples of 100 cm^3 were taken each time for determination of the moisture retention characteristics at 10, 33, 100 and 1500 kPa. Due to the fact that the field study was carried out during the dry winter season, the soils were (almost) dry. In order to be able, despite, to enter the rings in the soil, the levels that had to be sampled were wetted shortly before with help of the rings. The moisture content at 1500 kPa (i.e. the permanent wilting point) was also measured on the bulk samples.

Near each pit three infiltration measurements were done using the double ring[4] falling head method. A couple of hours after the end of the infiltration trial the depth of the wetting front was estimated with an auger and soil samples were by this way taken on two of the three replicates at depths corresponding to the main soil levels identified in the soil pit. The moisture content determined on these samples represents approximately the saturated water holding capacity. About 3 days after the infiltration trial the soil was again sampled under the two replicates at the same depths in order to have a field value of the 'drained upper limit' moisture content. At Pongola, Bruynshill and La Mercy was also determined the soil moisture content at the moment of the field study by sampling[5] with an auger at the same depths as it was done for the soil moisture measurements after the infiltration trail.
All the moisture and bulk density measurement were done by the soil physics laboratory of SASRI. In annex 3 are reported all the data concerning the samplings that were carried out.
Results of moisture content measurements obtained as weight percentage were converted in volumetric % by multiplying them with the mean value of results of the bulk density measurements done with the 250 cm^3 rings on the same soil levels.

---

[3] a weighting between 0 and 1 indicating the volume of roots in each soil layer
[4] entered about 8 cm in the soil; diameter inner ring between 30 and 35 cm; height of water level above soil surface about 22 cm at start of the test.
[5] without replicate

Soil chemical determinations were done on the collected bulk samples by SASRI's FAS laboratory as it commonly does on the samples it receives. The results include pH and an estimation for the % of organic matter[6] but not the CEC. In this study CEC will be estimated indirectly. FAS results include also estimation for the clay content[7], but the latter was also determined by the particle size analysis[8] done by SASRI's soil physics laboratory. Total N mineral N forms and organic carbon was also determined by the soil chemistry laboratory of SASRI.

Runoff number and albedo were not determined, but these characteristics can be deduced from the site descriptions given in annex 1 for each studied field. Root growth factor can be deduced from the soil pit descriptions which are given in the same annexe by transforming the root abundance assessments (very abundant to none or almost none, i.e. 5 levels) in figures rating from 0 to1.

3 - RESULTS AND COMMENTS

3.1. Soil types concerned by the study according to three taxonomy systems

The soils concerned by the study are named below according to the taxonomy system used in the SA sugarcane industry[9] as well as two international systems: the WRB (World Reference Base) system[10] and the one recommended by the USDA Soil Survey Staff [11]. It has to be noted that the naming to the international systems is approximately, notably because SASRI's laboratory did not determine CEC, ECEC and organic carbon on the soil samples

Mount Edgecombe farm

Field 41: Soils developed on dark grey shale of Permian age or on colluviums derived from such shales.
SA soil taxonomy: Tukulu soil form[12], Olivedale family (Orthic A, neocutanic B - from 60 to 70 cm –underlain by an oxidized G horizon),
WRB taxonomy: Gleyic Phaozem (?)
USDA taxonomy: Typic Haplustoll

Field 23: Soils developed on a dolerite intrusion in grey Permian shale
Southern and central part:
SA soil taxonomy: Arcadia (not calcareous) soil form (Vertic A, lithocutanic B on saprolite)
WRB taxonomy: Pellic Vertisol
USDA taxonomy: Udic Haplustert
Northern part:
SA soil taxonomy: Mayo soil form (Melanic A, lithocutanic B on saprolite and dolerite stones)
WRB taxonomy: Eutric Regosol
USDA taxonomy: Entic Haplustoll

---

6 by a NIRS method
7 by a NIRS method
8 according to a simplified version of an international standard method
9 Identification & management of soils of the South African Sugar Industry, 1999, published by SASEX
10 World Reference Base for Soil Resources (FAO/ISRIC/ISSS, 1998).
11 Soil Survey Staff. 1998. Keys to Soil Taxonomy, 8th ed. USDA-Natural Resources Conservation Service,
12 but Inhoek soil form, Cromley series, or Tambankul form, Fenfield series, if the A horizon is considered to be Melanic

La Mercy

Soils developed on shale and subordinate sandstone of Permian age

SA soil taxonomy: Swartland soil form, Rosehill series (Orthic A, pedocutanic B on not typical saprolite)

WRB taxonomy: Haplic Lixisol

USDA taxonomy: Ultic Haplustalf

Bruynshill farm

Soils developed on red-brown arkosic to subarkosic sandstone of the Natal group

SA soil taxonomy: Inanda soil form, Fontainhill soil series, (Humic A on red apedal B)

WRB taxonomy: Umbrihumic Ferralsol

USDA taxonomy: Humic Kandiustox

Pongola farm

Soil developed on colluviums derived from deeply metamorphosed Precambrian rocks

SA soil taxonomy: Hutton form (Orthic A, red apedal B), intergrade Shorrocks (15-35 % of clay in B) and Makatini series (clay is 35-55 %),

WRB taxonomy: Chromic Lixisol

USDA taxonomy: Haplustept

3.2. Rooting depth

Rooting depth, as recorded during the soil pit observation, is given in table 1. For conversion of the root abundance rates noted from 0 to 5 (table 1), in rates between 0 and 1, it is suggested to apply a factor 0.2 for abundance rates between 2 and 5 and with a factor 0.1 for the rate 1. In table 1 is also mentioned the maximum rooting depth attributed to the studied soil pits according to our field observations.

Table 1 : Root abundance and depth

Mt Edge 41		**Mt Edge 23S**		**Mt Edge 23N**	
depth	R code	depth	R code	depth	R code
0-10	5	0-7	4	0-5	4
10-21	4	7-45	3	5-25	3
21-49	3	45-90	2	25-45	2
49-120	2	90-140	1	45-100	1
120-170	1				
max depth	>170 cm	*max depth*	>140 cm	*max depth*	>140 cm
La Mercy		**Bruynshill**		**Pongola**	
depth	R code	depth	R code	depth	R code
0-20	5	0-42	4	0-130	4
20-45	4	42-75	3	130-150	2
45-80	2	75-130	2		
80-125	1	130-170	1		
max depth	>125 cm	*max depth*	±170 cm	*max depth*	>150 cm

Root abundance code: 5 = very numeroues, 1 = very few

3.3. Albedo

As mentioned above, no albedo measurements were carried out. According to the colour of the topsoil, its clay and organic matter content and its surface state in the absence of cane trash, we estimate the albedo for the studied soils:

- when they are without a cover of trash or cane crop and moist at top: about 0.05 in field 23 of Mt Edgecombe and 0.15 in all the other fields;
- about 0.05 point higher than above when the topsoil is dry or when it is covered by dead trash,
- about 0.25 under full cane canopy.

3.4. Runoff

Runoff curve number - which determines the amount of rainwater that does not infiltrate into the soil during events of heavy rainfall - was not determined. It can be deduced from data reported in this study.
Sugarcane being cropped at all the sites with similar erosion control techniques, the suitability to runoff depends only mainly on the physical characteristics of their topsoil and the slope of the field. Considering the results of the infiltration trials which were carried out (cf. 3.5) and the characteristics of the topsoil of the four fields with low slope[13], the Bruynshill field appears to be more prone to runoff[14] than the three others fields despite its higher content in organic matter. This fact seems to be induced by the low biological activity of the soil as well as the low activity of its clay fraction.
The intrinsic suitability to runoff of field 23 in Mt Edgecombe is low under the prevailing climatic conditions[15]. But, due to it's noticeably slope (15 to 25 %), runoff will occur during rainy events. This probably explains why the soils of field 23 are less deep than in the other sites.

3.5. Saturated hydraulic conductivity

The saturated hydraulic conductivity of the main soil levels was deduced from measurements done at the surface of the soil with the double ring falling head method after pre-wetting of the topsoil. The decrease in infiltration rate with time observed in most of the trials was supposed to correspond to a lower infiltration rate of deeper soil layers attained by the wetting front. The hereunder reported data are mean values of the results of three measurements, all (except at Bruynshill) done on initially dry soils. Details data on the procedure and results are given in annex 4.

Mount Edgecombe, field 41
* ± 40 cm/h (= very high) in top part of the (very porous) topsoil
* 20 ± 5 cm/h in bottom part of the A horizon
* ± 8 cm/h in the (neocutanic) subsoil and deeper layers.
Remark: data obtained at a trashed site[16]

Mount Edgecombe, field 23
Southern (and main) part of the field
* 105 ± 25 cm/h in the upper part of the (very porous) topsoil
* 22 ± 16 cm/h in the vertic A horizon
Northern part of the field
* 60 ± 10 cm/h (very high) in the upper part of the topsoil
* 14 ± 3 cm/h (high) in thin vertic A horizon

---

13 All have a slope between 3 and 5 %, except Mt Edgecombe 23.
14 High runoff during rainy events was reported by the farm manager.
15 Most of the rain falls with low intensity.
16 in a cropped "break" of the trial

Remarks: After long rainy events the steady infiltration rate will probably be much lower, but such kind of events exists probably seldom in Mt Edgecombe. In case of such event the risk of runoff on this steep field 23 is greater in its northern part, a fact which is attested by differences in soil surface state and texture as well as the presence of runoff/ erosion figures.

La Mercy (Tongaat-Hulett)
* 20 to 30 cm/h in the very topsoil:
* progressively down to 5-6 cm/h below 70 cm depth

Bruynshill, field n° 6A
* 9 ± mm/h in topsoil
* 7 ± 1 mm/h immediately below
* distinctly higher in deeper layers.

Pongola, field 318
* very topsoil: ± 5cm/h in compacted sites, up to 22 cm/ in not compacted sites
* subsoil = 13 ± 3 cm/h;

3.6. Bulk density (Bd)

According to the results obtained with 250 cm^3 ring samples in 2 replicates, the mean Bd values are those reported in table 2. The mean values for Bd obtained with three 100 cm^3 rings are reported in table 3.
Compaction during sampling being more easily avoided with large rings, only the results obtained with the 250 cm^3 rings will be considered below, as far as possible.
Bulk density data obtained with 250 cm^3 rings, generalized to the soil profile by taken into account the thickness of the distinguished soil horizons, are shown in table 4.

3.7. Saturated water holding capacity

According to the bulk density measurements done with the 250 cm^3 rings and assuming the particle density is 2.65[17], the total porosity, generalized for the total soil profile, is as shown in table 5. The closed porosity in soil material being about 3 %, the saturated water holding capacity is thus theoretically 3% less than the figures shown in table 5.
In table 6 is shown the maximum volumetric water content of the five soils after the end of the infiltration trial. For conversion of the moisture content measured in weight % into volumetric % were used the Bd results presented in table 4. Comparison of table 6 with table 5 reveals that the saturated water holding capacity was not reached after the infiltration trial and will probably never been reached in the studied soils[18].

3.8. Drained upper limit & air filled porosity

Data for drained upper limit of moisture content (usually called 'field capacity') as measured in weight % by sampling three days after the end of the infiltration trial and converted in

[17] In fact somewhat lower for horizons containing noticeable amount of organic matter and about 2.7 g/cm^3 for heavy clay soils
[18] Except probably in field 41 of Mt Edgecombe where signs of hydromorphic conditions were observed at depth greater than 80 cm and which are possibly due to the presence of a seasonal perched water table. At the moment of the study, the deep subsoil was humid.

volumetric % by the figures presented in table 4, are given in table 7[19]. Data for field capacity measured on the 100 cm^3 undisturbed ring samples with a pressure membrane apparatus at 10 kPa, as is usually done at SASRI, are presented in table 8.[20]
Comparison of these two series of results shows that the values obtained by the second method are systematically higher and often much higher then those obtained by the first method. This is surprising because, theoretically, the "good" data obtained by the second method should even be higher as those shown in table 8 due to the fact that for the considered not sandy soils the measurement of the field capacity should had been done at a suction of 5 kPa.

According to our opinion, the values presented in table 7 present most likely the real field capacity of the studied soils, because the used moisture values correspond to the definition of field capacity.
Another reason for this statement is that values for air filled porosity[21] are for Mt Edgecombe 23 and 41 as well as for La Mercy - except in their top layer - below the commonly admitted threshold value of 10 % at 10, 33 and 100 kPa and sometimes even at 1500 kPa (see table 9). We can not believe that such low values of air filled porosity really exist in these soils because that should involve that cane-root activity in these layers will stop when they are moist. Probably, something went wrong during the measurements of the moisture retention at different suctions in the laboratory.

3.9. Lower limit of moisture content (or Permanent Wilting Point)

The volumetric water content at the lower limit of moisture in the soil for plant growth is presented in table 10 for the studied sites. The data presented in this table are based on the depth * bulk density values presented in table 4 and the results of the moisture content measurements done at a suction of 1500 kPa (see annex 6) according to the conventional method[22] on the bulk samples taken at the considered depth levels. If for the considered depth –bulk density level several moisture measurements results were obtained (several times 2, once even 3) their mean value was used for the calculation of the volumetric water content at 1500 kPa. For the data concerning Mt Edgecombe 23N we are admitted that the bulk density was for similar soil horizons similar to those measured in pit Mt Edgecombe 23S.

Usually the moisture content at 1500 kPa as measured in weight % is ruled only by the % clay of the soil sample and by the familly to which belongs the clay fraction. By separating the soils according to the distinct CEC group to which belong their clay fraction, different regressions are obtained. In our case, the best regression (H%ww-16bar = -1.40 +0.486* %

---

[19] For unknown reason the results of the moisture content measurements done on the by auger samples taken in field 23 of Mt Edgecombe after the infiltration trial are partly irrelevant. For this reason the presented values are indicative. Bulk density values measured on site 23 S were used for conversion of the results of moisture weight measurements on site 23N in volumetric moisture content.
[20] The mean value of the data obtained on the 100 cm3 ring samples at 10, 33, 100 and 1500 kPa are shown in annex 5.
[21] As deduced from the volumetric moisture content measurements done at 10, 33, 100 and 1500 kPa.
[22] On soil crushed to ≤2mm and put in small rings.

Table 2: Bulk density according to 250 cm^3 ring sampling (depth in cm)

Mt Edge 41		Mt Edge 23 S		La Mercy		Bruynshill		Pongola	
depth	Bd	depth	Bd	depth	Bd	depth	Bd	depth	Bd
0 - 5	*1.37*	0 - 5	*1.25*	5 - 10	*1.51*	10-15	*1.38*	5 - 10	*1.59*
30 - 35	*1.65*	15 - 20	*1.14*	30-35	*1.56*	32 - 37	*1.29*	23 - 28	*1.59*
60 - 65	*1.63*	50 - 60	*1.12*	60-65	*1.25*	60 - 65	*1.36*	55 - 60	*1.42*
95 - 100	*1.40*	90 - 95	*1.17*			125 - 130	*1.16*	90 - 95	*1.41*

Table 3: Bulk density according to 100 cm^3 ring sampling

Mt Edge 41		Mt Edge 23S		La Mercy		Bruynshill		Pongola	
depth	Bd	depth	Bd	depth	Bd	depth	Bd	depth	Bd
0-5	*1.51*	0-5	*1.26*	5 - 10	*1.53*	10-15	*1.36*	5-10	*1.47*
15-20	*1.71*	30-35	*1.13*	30 - 35	*1.60*	32-37	*1.31*	23-28	*1.73*[23]
50-55	*1.66*	60-65	*1.09*	60 - 65	*1.35*	60-65	*1.38*	55-60	*1.47*
90-95	*1.48*	± 95	*1.24*			125-130	*1.35*	90-95	*1.51*

Table 4: Bulk density data generalized to the observed soil profiles

Mt Edge 41		Mt Edge 23 S		La Mercy		Bruynshill		Pongola	
depth	Bd	depth	Bd	depth	Bd	depth	Bd	depth	Bd
0-10	1.37	0-10	1.25	0-20	1.51	0-20	1.38	0-40	1.59
10-20	*1.50*	10-140	1.15	20-45	1.56	20-40	1.29	40-130	1.42
20-75	1.64			45-125	1.25	40-75	1.36		
75-120	1.40					75-105	*1.30*		
						105-130	1.24 *		

*Interpoled values are in italique; * mean value of 100 and 250 cm^3 rings*

Table 5: Total porosity (% cm^3/cm^3) for the five soil pits

Mt Edge 41		Mt Edge 23 S		La Mercy		Bruynshill		Pongola	
depth	Por tot	depth	Por tot	depth	Por tot	depth	Por tot	depth	Por tot
0-10	48.3	0-10	52.8	0-20	43.0	0-20	48.0	0-40	40.0
10-20	*43.4*	10-140	56.6	20-45	41.1	20-40	51.5	40-130	46.2
20-75	38.1			45-125	52.8	40-75	48.9		
75-120	47.2					75-105	*50.9*		
						105-130	53.2		

Table 6: Maximum volumetric water content (% cm^3/cm^3) after the infiltration trial

Mt Edge 41		Mt Edge 23 S		La Mercy		Bruynshill		Pongola	
depth	%v/v	depth	%v/v	depth	%v/v	depth	%v/v	depth	%v/v
0-10	24.8	0-10	43.9	0-20	30.8	0-20	40.4	0-40	32.3
10-20	27.1	10-70	48.6	20-45	29.7	20-40	36.2	40-130	32.2
20-75	26.6	70-140	46.2	45-125	35.0	40-75	36.2		
75-120	36.2					75-105	34.7		
						105-130	33.9		

[23] high Bd due to compaction during sampling; result not used for moisture retention and air filled porosity data

Table 7: Volumetric water content (% cm^3/cm^3) for the five sites 3 days the infiltration trial

Mt Edge 41		**Mt Edge 23 S**		**Mt Edge 23 N**		**La Mercy**		**Bruynshill**		**Pongola**	
depth	% v/v	depth	% v/v	depth	% v/v	depth	% v/v	depth	% v/v	depth	% v/v
0-10	22.0	0-10	41.2	0-5	31.0	0-20	27.6	0-20	32.4	0-40	28.9
10-20	24.1	10-70	42.0	5-45	30.6	20-45	28.7	20-40	30.0	40-130	30.0
20-75	26.4	70-140	34.5	45-100	34.2	45-125	33.4	40-75	31.0		
75-120	36.9							75-105	32.3		
								105-130	33.2		

Table 8: Volumetric water content at 10kPa on 100 cm^3 rings, mean value

Mt Edge 41		**Mt Edge 23 S**		**La Mercy**		**Bruynshill**		**Pongola**	
depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %
0-5	30.6	0-5	42.7	5 - 10	31.8	10-15	35.3	5-10	31.3
30-35	*n.r.*	30-35	53.9	30 - 35	32.6	32-37	36.9	23-28	*n.r.*
60-65	32.9	60-65	53.0	60 - 65	41.9	60-65	36.6	55-60	31.2
± 95	40.9	± 95	50.6			125-130	39.5	90-95	33.9

n.r.: not relevant

Table 9: Air filled porosity (% cm^3/cm^3) of 100 cm^3 rings between 10 and 1500 kPa, mean values

depth	10 kPa	33 kPa	100 kPa	1500 kPa
		Mt Edge 41		
0-5	12.6	13.9	15.4	19.5
30-35	*6.8*	*7.7*	*8.8*	12.3
60-65	*4.4*	*5.3*	*6.3*	*8.4*
± 95	*3.2*	*3.8*	*4.9*	*7.4*
		La Mercy		
5 - 10	10.6	11.4	12.3	18.8
30 - 35	*7.0*	*8.7*	*9.8*	13.8
60 - 65	*7.1*	*7.5*	*8.1*	12.8
		Pongola		
5-10	13.3	14.6	14.6	18.2
55-60	13.4	14.0	15.1	22.1
90-95	*9.1*	*9.9*	10.8	20.1

depth	10 kPa	33 kPa	100 kPa	1500 kPa
		Mt Edge 23 S		
0-5	*9.9*	10.9	11.6	17.7
15-20	*3.3*	*4.1*	*5.7*	10.0
50-55	*5.8*	*7.6*	*9.2*	13.0
90-95	*2.7*	*4.9*	*4.9*	*8.3*
		Bruynshill		
10-15	13.3	14.7	15.4	21.7
32-37	13.8	14.9	15.3	24.3
60-65	11.1	12.3	12.6	21.3
125-130	*9.6*	10.9	11.3	19.9

*Table 10: Volumetric water content (cm^3/cm^3) at Permanent Wilting Point for moisture content by weight at 1500 kPa **not** corrected*

Mt Edge 41		**Mt Edge 23S**		**Mt Edge 23N**		**La Mercy**		**Bruynshill**		**Pongola**	
depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %
0-10	11.1	0-10	33.0	0-5	16.7	0-20	20.2	0-20	19.7	0-40	20.7
10-20	16.0	10-65	38.1	5-45	24.7	20-45	18.1	20-40	16.2	40-130	17.2
20-75	15.1	65-140	35.6	45-100	27.2	45-125	27.2	40-75	16.6		
75-120	26.5							75-105	17.3		
								105-130	17.8		

Clay, R^2=0.73[24], n= 26) is obtained when "moisture - % clay" data of the subsoil of pits 23 N and 23 S[25] are set apart[26].
New moisture values at the permanent wilting point were calculated for each sampled horizon with the above mentionned regression and were with the bulk density values reported in table 4 converted in volumetric moisture content values. These data are shown in table 11.
According to our opinion, the data presented in table11 are more likely to correspond to the effective moisture content at PWP than those of table 10 and they will for this reason be used for the calculation of the total available water-holding capacity.

It should be noticed that moisture content values obtained at 1500 kPa on the 100 cm^3 ring samples are much higher[27] than those obtained by the classical method. For this reason they will not be considered here. This explains also why so much values of air filled porosity obtained by measurements with 100 cm^3 ring samples are lower then the 10 % threshold value as is shown in table 8

Table 11: Volumetric water content (cm^3/cm^3) at Permanent Wilting Point for corrected moisture content by weight at 1500 kPa

Mt Edge 41		**Mt Edge 23S**		**Mt Edge 23N**		**La Mercy**		**Bruynshill**		**Pongola**	
depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %	depth	Hv %
0-10	10.0	0-10	33.6	0-5	21.1	0-25	17.8	0-20	17.2	0-40	18.9
10-20	11.8	10-65	34.2	5-45	18.5	20-45	21.4	20-40	17.9	40-130	22.9
20-75	17.8	65-140	32.8	45-100	32.8	45-125	31.8	40-75	21.3		
75-120	28.3							75-105	22.9		
								105-130	24.3		

3.10. Total available moisture content (TAM)

The total available moisture content for plant growth for each of the 6 soil profiles is presented in table 12. This characteristic is the difference between the data presented in tables 7 and 11 and is in table 12 expressed in mm of water per soil level and for the top meter of each studied soil.
Results tend to show that the total available water capacity is correct in field 41 of Mt Edgecombe and at Bruynshill, moderate in Pongola, but low at Le Mercy and in field 23 of Mount Edgecombe.
As already suggested in § 3.7, the values for field 23 of Mount Edgecombe are indicative because irrelevant data were reported for moisture measurements done on samples taken after the infiltration trial.
It has to be noted that the obtained values for TAM are lower than suggested at page 158 of the handbook "Identification & management of the soils of the SA sugar industry".

[24] Far below a R^2 of 0.98 and for n=25 established by the author for West African soils with kaolinitic clays
[25] They have a sum of exchangeable cation per kg of clay much higher than the other sampled soil horizons; see soil chem. data in annex 7.
[26] The equation for n=29 is H%w/w-16bar = 4.26 +0.38 %Clay, **R2 = 0.38**.
[27] H % w:w- cyl-16 bar = 6.212 + 0.968*H%w/w -2mm- 16 bar; R^2 0.91, n= 18

Table 12: Total available moisture (mm) per soil level & soil profil

Mt Edge 41		Mt Edge 23 S		Mt Edge 23 N		La Mercy		Bruynshill		Pongola	
depth	mm	depth	mm	depth	mm	depth	mm	depth	mm	depth	mm
0-10	12.1	0-10	7.6	0-5	5.0	0-25	19.7	0-20	30.4	0-40	40.2
10-20	24.6	10-65	43.3	5-45	48.4	20-45	18.2	20-40	24.2	40-100	42.4
20-75	47.8	65-100	6.0	45-100	8.1	45-100	8.6	40-75	33.9		
75-100	21.6							75-100	22.3		
0-100	***106.0***	***0-100***	***56.9***	***0-100***	***61.4***	***0-100***	***46.5***	***0-100***	***110.7***	***0-100***	***82.6***
add 10 cm	*8.7*	*add 10 cm*	*1.7*	*add 10 cm*	*1.5*	*add 10 cm*	*1.6*	*add 10 cm*	*8.9*	*add 10 cm*	*7.1*

3.11. Other soil characteristics and remarks

Other collected data as already shown in tables 1 to 12 are reported in annexes 6 to 8. In these annexes are also reported the analytical data obtained on sampling done at two levels in field 306 of the Pongola farm at the request of Rob Donaldson.

A. Comments on annex 6

In annex 6 are reported the results obtained on the bulk samples by the soil physics laboratory concerning the particle size distribution and of the moisture retention at 15000 kPa as well the estimation of the clay percentage done by the FAS laboratory on the same samples. In the same table of the annex 6 is also indicated the textural class for each sample.
Regression analysis of the two series clay percentage shows that between 18 and 69 % clay:
*Clay % FAS = 6.35 + 0.80 * % Clay-Soil Physics Lab (R^2=0.93, n=28)*

Despite the high R^2 of this equation, it should not be used by FAS for correction of the clay % it obtains with a NIRS method. Indeed, a comparison of the two series of results shows that at a low % of clay the FAS method over estimated it and that at a high content it under estimates the clay %.

As already reported in § 3.9, the best regression between the gravimetric moisture content at 1500 kPa and the clay content as determined by the soil physics laboratory is H% = -1.40 +0.486* % for R^2=0.73, n= 26. That is not satisfactory, because much better regressions (with a constant almost nil and $R^2 > 0.90$) were reported in other studies.
The absence of a better relation between % clay and moisture content at 1500 kPa than the one obtained for this study is very probably due to the fact that the determination of the particle size distribution is at SASRI is done according to a simplified version of the international standard method.

B. Comments on annex 7

In annexe 7 are reported pH water, exchangeable Ca, Mg, K, Na and Al for all the collected bulk samples. On the table are also reported the calculated values of:
- The sum of cations (Σ) which can be assimilated to the CEC,
- The Potassium+ Sodium absorption ratio (KSAR) on the CEC,
- The ratio 'sum of cations'/clay % expressed in cmol per kg of clay which can be assimilated to activity of the clay fraction.

The reported data show:
- The whole profile of the Bruynshill soil is acidic ((pH 4.8 to 5.1) and characterised by a very low activity of its clay fraction (only about 5 cmol per kg clay[28]). All the other soils have a convenient pH, except the topsoil of La Mercy which is also acidic;
- The subsoil of field 23 at Mt Edgecombe which consists of weathered dolerite tends to show an unusual very high activity of its clay fraction. Probably this is an artefact due to the fact that the silt and fine sand fractions of the weathered basic rock contain probably exchangeable Ca and Mg. The subsoil of Mt Edge 23 N is also characterised by a very high pH. Possibly this is due to the presence of some bicarbonate of sodium;
- The K level of the top soil is convenient in all sites except Mt Edge 41, where K is low, and in Pongola 306[29], where it is marginal.
- The topsoil of Bruynshill shows a high KSAR, mainly due to its high level in exchangeable regarding the low sum of cations. This characteristic makes to soil very sensitive to structure deterioration.

C. Comments on annex 8

The analytical results relative to the organic matter of the studied soils, their nitrogen content and their amount of available phosphorus are reported in the table of annex 8.

P

According to the reported results, the P level of the topsoil is high at Bruynshill, convenient in Pongola 318, but low in Mt Edgecombe 41 and 23 N. A surprising result is that P level in the subsoil of Mt Edgecombe 23N is very high when, as commonly is observed, its level is low in all the other sampled soil pits. This unusual result may be due to an error or a contamination during the analysis.

C and C/N

Data of total organic matter reported by the chemical laboratory are most of time as expected but show also some strange results, i.e. % of OM lower in top horizon(s) of Mt Edge 41 and La Mercy than in deeper layers. Data for total nitrogen following the normal decreasing trend with soil depth, only a mistake during the determination of organic carbon may explain these strange results. This explains also why the considered soil levels have such an abnormal high C/N[30]: C/N 20 to 40.
Several other analysed soil horizons show also a high and in some case a very low C/N ratio. This may be due to a high incertitude on the precision of the results of the C and or N measurements.
Concerning the estimation of the organic matter % by FAS it should be mentioned that the correlation with the results obtained by the chemistry laboratory is bad: OME % = 0.055 + 0.843* OM%; n=29, $R2= 0.487$.

N mineral

As expected, the value for total mineral nitrogen is somewhat low, but at normal level for a crop that was already harvested (Bruynshill) at the moment that the sampling was done or had to be harvested some weeks or months later.

---

[28] After deduction of the contribution to the CEC of the soil organic matter
[29] Very surprising is the big difference in the level of available K between the two sampled fields at Pongola
[30] Usually the C/N ratio in the topsoil is between 10 and 14. It may be higher in conditions of slow decomposition of organic matter (40 or more in peaty soils), but lower in well oxygenised subsoil

ANNEX 1: Site and pit description – soil taxonomy

1. Mount Edgecombe, field 41

Site characterisation:
Date: 28 Mai -2 June 2008
Land use: sugarcane, trashed
Soil surface: smooth granular under trash but with surface crusting in absence of trash
Topographic position: mid slope
Slope: General slope 5 % oriented NNW, diagonal across the trial; lateral slope (of field road bordering the trail) 2-3 %
Parent material: dark grey shale (of Permian age, Pietermaritzburg formation, Ecca group, Karoo sequence).
Location soil pit: center of Southern break; altitude: 97 m; 29°42.440' S, 031°03.015'E (WGS 84 projection)

Soil classification
- *according to SA system*: Tukulu soil form[31], Olivedale family (Orthic A, neocutanic B - from 60 to 70 cm –underlain by an oxidized G horizon),
- *According to WRB taxonomy*: Gleyic Phaozem (?), *USDA taxonomy:* Typic Haplustoll

Pit description
0-10 cm: Ap1; dry; very dark brown (10YR2/2, when moist), sandy loam to loam texture with fine sand and very few gravel; distinct fine to very fine subangular blocky structure; friable, slightly sticky and plastic, slightly hard consistence; very numerous roots mostly horizontal, numerous traces of biological activity, very porous; clear (2 cm), wavy boundary with
10-21 cm: Ap2; dry; very dark brown (10YR2/2) sandy loam to loam with fine sand and very few gravel; weak apedal structure with moderate fine subangular blocky sub structure; friable, slightly sticky and plastic, slightly hard consistence; numerous roots, numerous traces of biological activity, porous; clear (5 cm) smooth boundary with
21-49 cm A; dry; very dark brown (10YR2/2) sandy clay loam/loam with very few gravel; apedal structure with angular fragments; friable, slightly sticky and plastic, slightly hard consistence; roots, few traces of biological activity, porous; gradual (10 cm) smooth boundary with
49-73cm AC?; dry; dark brown (10YR3/3) sandy clay loam to loam with very few gravel; apedal structure with angular fragments; friable, slightly sticky and plastic, slightly hard consistence; few roots & few traces of biological activity, porous; gradual (15 cm) smooth boundary with
73-120cm CGox; dry; very dark greyish brown (10YR3/2) clay loam/loam with red (2.5YR 5/6) and brownish yellow (10YR6/8) mottling; apedal structure with angular fragments; friable, sticky and plastic, hard consistence; few roots & traces of biological activity, porous.
By augering:
120-170 cm: CGox; slightly humid; clay loam, red (2.5YR 5/6) with brownish yellow (10YR6/8) & gray (2.5YR 5/1), mottling, some roots
170–220 cm: CGox; fresh; clay loam, brownish yellow (10YR6/8) with red (2.5YR 5/6) & grey (2.5YR 5/1) mottling

[31] but Inhoek soil form, Cromley serie, or Tambankul form, Fenfield serie, if the A horizon is considered to be Melanic

220–245 cm. CGox; humid; clay loam, light gray (10YR5/1 to 7/1) with light red (2.5YR 6/6) & yellowish red (5YR 5/6) mottling

Remarks:
- Crop water needs during dry spells probably satisfied by a perched seasonal water table,
- Maximum effective rooting depth about 170 cm.

2. Mount Edgecombe, field 23, sector South.

Site characterisation:

Date: 29 Mai -2 June 2008
Land use: sugarcane (propagation field)
Soil surface: no trash, cane planted in contour lines with some up hilling of the rows; a few gravel and small stones of dolerite (5%) and some of lime (!); scattered shrinkage cracks; erosional surface state with small granular porous aggregates scattered at the surface
Topographic position: mid slope, 15 %, oriented NE
Parent material: dolerite (Jurassic intrusion in the grey shale of the Pietermaritzburg formation)
Location soil pit: center of the Southern and central parts of the field; altitude: 97 m; 29°42.251' S, 031°02.355'E (WGS 84 projection)

Soil classification
- *According to SA system*: Arcadia (not calcareous) soil form (Vertic A, lithocutanic B on saprolite and hard dolerite stones):
- *According to WRB taxonomy*: Pellic Vertisol, *USDA taxonomy:* Udic Haplustert

Pit description
0-7 cm: Ap; dry; very dark brown (10YR2/1, when moist) clay with fine sand and some hard gravel of dolerite; distinct fine subangular blocky with coarse subangular blocky sur structure; slightly hard when dry, friable when moist, sticky when wet; cracks of 4 mm width, each 40 cm; numerous roots , porous; abrupt and smooth boundary with
7-23 cm: A12; slightly humid; colour, texture, roots, plasticity and stickiness similar to Ap; distinct fine angular blocky structure with coarse prismatic sur structure; hard when dry, cracks of 4 mm, low porosity, distinct wavy boundary with
23-45 cm: A3; slightly humid; very dark brown (10YR2/1) with dark yellowish brown (10YR4/4) mottles; texture, structure, consistence & porosity similar to 7-23 cm; roots less abundant, gradual wavy boundary with
45-65 cm: Bv; slightly humid; yellowish red (5YR4/6) clay with abundant very dark brown (10YR2/1) to dark grey (10YR4/1) humic patches related to voids and roots, few living roots, distinct fine angular blocky structure; some polished surfaces and slickensides; texture, consistence & porosity similar to 7-23 cm; some weathered dolerite stones; gradual wavy boundary with
65- 90 cm C-CA; slightly humid; brownish yellow (10YR6/8) silty clay loam with very dark brown (10YR3/2) humic mottles or tongues; massive structure with subangular breaking fragments; about 10 % almost weathered dolerite stones, few roots, porous; gradual wavy boundary with
90-140 cm C-R; dry; strong brown (7.5YR5/6) and yellowish red (5YR5/6) clay loam with as above, massive structure with subangular breaking fragments; some almost weathered dolerite stones, very few roots, porous

Remarks:
- The fact that the soil is slightly humid after a long period of dry weather is surprising. This is probably due to subsurface lateral flow of waste water coming from the houses located above the trial;
- Sampled soil pit and in situ infiltration measurement were done in stool missing sectors,
- The limestones encountered at the surface of the soil are of anthropic origin,
- Maximum rooting depth > 140 cm.

3. Mount Edgecombe, field 23, sector North

Site characterisation:

Date: 30 Mai -2 June 2008
Land use: sugarcane (propagation field)
Soil surface: no trash, cane planted in contour lines with some up hilling of the rows; gravel and small stones of dolerite (5%) and some of lime (!); few fine scattered shrinkage cracks; erosional surface state with loamy deposits and small granular porous aggregates scattered at the surface.
Topographic position: mid slope, 22-25 % oriented NNE;
Parent material: dolerite (Jurassic intrusion in the grey shale of the Pietermaritzburg formation)
Location soil pit: center of the Southern and central parts of the field; altitude: 90 m; 29°42.221' S, 031°02.856'E (WGS 84 projection)

Soil classification

- *According to SA system*: Mayo soil form (Melanic A, lithocutanic B on saprolite and hard stones of dolerite):
- *According to WRB taxonomy*: Eutric Regosol, *USDA taxonomy:* Entic Haplustoll

Pit description

0-5 cm: Ap; dry; very dark brown (10YR2/1, when moist) clay with fine sand and some hard gravel of dolerite; distinct very fine subangular blocky structure and weak coarse subangular blocky sur structure; slightly hard when dry, friable when moist, sticky when wet; cracks of 2 mm width 60 cm apart; numerous roots and traces of biological activity, very porous; abrupt and smooth boundary with
5-25 cm: A12; almost dry; colour, texture, gravel, roots and consistence similar to Ap; distinct fine angular & subangular blocky structure with prismatic sur structure; low apparent porosity and biological activity; very fine cracks; distinct and wavy boundary with
25-45 cm: AC; slightly humid; very dark brown (10YR2/1) clay with brownish yellow (10YR6/6) mottles, 15 % ± weathered stones and gravel of dolerite; angular blocky structure; few roots, low apparent porosity and biological activity; no cracks; gradual and wavy boundary to
45-100 cm: C or (R); dry; yellow ((10YR7/6) with very dark grey (10YR3/1) spots of weathered argilified dolerite; 25 % ± weathered stones and gravel of dolerite; very few roots, porous

Remarks:
- Particle size determination reveal that the texture of the soil is sandy clay loam to clay loam e.g. less clayey that in pit 23 S,
- Maximum rooting depth > 100 cm;
- Cane leaves show moisture stress signs during the day.

4. La Mercy farm (of *Tongaat-Hulett*)

Field number: 13221 (previous 200)
Date: 7-10 July 2008
Land use: sugarcane, rain fed, 1, 5 month before harvest,
Soil surface: smooth with little trash and, locally, a sandstone boulder; traces of mole and ants activity,
Topographic position: convex crest; slope 3 %, oriented NW;
Parent material: shale and subordinate sandstone of the Vryheid formation (of the Ecca group of the Karoo Permian sequence)
Location soil pit: center of the field; 29°36.971'S, 31°05.226'E, altitude: 99 m ASL

Soil classification
- *According to SA system*: Swartland soil form, Rosehill series (Orthic A, pedocutanic B on not typical saprolite)
- *According to WRB taxonomy*: Haplic Lixisol; *USDA taxonomy:* Ultic Haplustalf

Pit description
0-20 cm: Ap, dry; very dark grey (10YR3/1) sandy clay loam with some sandstone gravel (<2 %); fine subangular blocky structure; plastic when wet, friable when moist, slightly hard when dry; porous; abundant roots & traces of biological activity; clear, wavy boundary to
20-45 cm A12, dry; very dark grey (10YR3/1) sandy clay loam with some gravel; fine angular blocky with apedal surstructure; plastic when wet, friable when moist, hard when dry; low macro porosity, numerous roots, few traces of biological activity; gradual smooth boundary to
45- 80 cm: A3 &B, dry; clay loam with some gravel; very dark grey (10YR3/1) variegated with reddish brown (2.5YR4/4); fine angular blocky with apedal surstructure; plastic when wet, friable when moist, hard when dry; low macro porosity, few roots and traces of biological activity; diffuse smooth boundary to
80-125 cm C, dry; clay loam with 5 % of hard and partly weathered sandstone stones; reddish variegated brown (2.5YR4/4) with very dark grey (10YR3/1) skins associated to voids and ped surfaces; very few roots and traces of biological activity, low porosity.

Remarks: Maximum rooting depth up to about 2 m in sub horizontal shale and sandstone, according to deep soil cuts existing near the field due to construction works for the new Durban airport.

5. Bruynshill farm, field 6A

Date: 9 -12 June 2008
Land use: sugarcane planted in contour lines, after harvest of last ratoon, treated with round-up;
Soil surface: trash on 50%, else flat surface state with sealing
Topographic position: near mid slope, 5 % oriented NE;
Parent material: Red brown arkosic to subarkosic sand stone of the Natal group (Ordovician-Silurian age)
Location soil pit: center of the part of the field useful for trials; altitude: 1015 m; 29°25'13.445"S, 030°'40'39.660"E

Soil classification
- *According to SA system*: Inanda soil form (Humic A on red apedal B); Fontainhill soil serie
- *According to WRB taxonomy*: Umbrihumic Ferralsol; *USDA taxonomy:* Humic Kandiustox

Pit description
0-22 cm: Ap; dry; very dark greyish brown (10YR3/2) sandy clay loam with few quartz gravels & some small soft lime clusters, locally abundant at the bottom of the horizon; distinct apedal structure with angular break fragments; slightly plastic when humid; friable; numerous roots, low porosity & biological activity; distinct and wavy boundary to
22-42 cm: A12; dry; dark brown (10YR3/3) sandy clay loam with few quartz gravels; distinct apedal structure with angular fragments; slightly plastic when humid; friable; numerous roots, low porosity & biological activity; distinct and wavy boundary to
42-75 cm: A3; slightly humid; dark brown (7,5YR3/3) clay loam with few quartz gravels; distinct apedal structure with angular fragments; slightly plastic when humid; friable; roots, low porosity & low biological activity; distinct and wavy boundary to
75-105 cm: AB; slightly humid; dark reddish brown (5YR3/4) and yellowish red (5YR4/6) clay loam; apedal structure with angular fragments; plastic when humid; friable; few roots, low porosity & low biological activity; distinct and wavy boundary to
105-130 cm: B; slightly humid; red (2,5YR4/6) clay loam; apedal structure with subangular break fragments; plastic when humid; friable; few roots, low porosity & low biological activity
By auger:
130-170 cm: humid, similar to 105-130 cm,
170-180 cm: C; coarse sand red and yellow with inclusions (tongues?) of red clay loam

Remarks:
- The soft lime stones and gravels are remnants of the application of filtermud done in the past. Being locally abundant, it is believed that the application was done in the furrows before planting.
- Compaction by infield traffic occurs during harvest.
- The steady water infiltration rate at surface of the soil is very low (7 mm/h) as compared to other soils under cane and the soil biological activity is also very low (no evident signs of noticeable ants or termites activity).
- Instant infiltration rate of deeper layers is higher then on topsoil.
- Maximum rooting depth approximately 170 cm

6. Pongola farm, field 316

Date: 17-20 June 2008
Land use: sugarcane with drip irrigation, 1 month after harvest,
Soil surface: trash blanked
Topographic position: upper part of piedmont slope; 3 % oriented NE;
Parent material: Colluviums derived from Precambrian deeply metamorphosed rocks of the Pongola sequence consisting in quartzite, shale, siltstone, sericite and amphibolite schist
Location soil pit: between rows 1 & 2 from field road between fields 316 & 315, about 20 m from field road between blocks 2 & 3. Field equipped with larges lysimeters.
Altitude: 306 m; 27°24,884'S, 031°35,675'E

Soil classification

- *According to SA system*: Hutton form (Orthic A, red apedal B), intergrade Shorrocks (15-35 % of clay in B) and Makatini series (clay is 35-55 %),
- *According to WRB taxonomy*: Chromic Lixisol; *USDA taxonomy:* Haplustept

Pit description
0-18 cm: Ap, slightly humid; dark reddish brown (5YR3/3) sandy clay loam; slightly plastic; friable; apedal structure breaking in angular fragments, under the cane rows often also fine subangular blocky structure; porosity low, but locally important; numerous roots –most often horizontal - and signs of biological activity; distinct smooth boundary with
18-40 cm: A3, humid, dark reddish brown (2.5YR2.5/4) sandy clay loam, slightly plastic; friable; porous, numerous roots, mostly vertical; numerous signs of biological activity; gradual smooth boundary with
40-75 cm: B&A, humid, dark reddish brown (2.5YR3/4) clay loam; apedal structure breaking in angular fragments; plastic; friable; porous; numerous roots; sign of biological activity; gradual smooth boundary with
75-130 cm: B2, dry, dark reddish brown (2.5YR3/4) clay loam; apedal structure; numerous roots; sign of biological activity; distinct smooth boundary with
130-150 cm: IIB3, dry, dark reddish brown (2.5YR3/4) sandy clay loam with about 75 % gravel and stones of quartzite and arkosic sandstone; few roots.

Remarks:
- Compaction occurs by infield traffic at harvest,
- Maximum rooting depth >150 cm, but > 130 cm developed in a very gravelly-stony colluvium

Annex 2: Substratum-geology of the 5 fields

(According to 1/250 000 geological maps, except if otherwise mentioned)

Mont Edgecombe
Field 41: Dark grey shale of the Pietermaritzburg formation (Pp) of the Ecca group (Permian age) of the Karoo sequence.
Field 23: Intrusion of Jurassic dolerite in the Pp formation

La Mercy
Sandstone with grit beds, subordinate grey shale & sandstone, Pv = Vrijheid formation of the Ecca group of the Karoo Permian sequence

Bruynshill:
Red brown arkosic to subarkosic sandstone (Osn = Ordovician-silurian Natal group). Note: the Glenside farm is also located on the Osn series but in a sector where dominates quarzitic sandstone.

Pongola:
Colluviums derived from Precambrian deeply metamorphosed rocks of the Pongola sequence consisting in quartzite, shale, siltstone, sericite and amphibolite schist according to the 1/250 000 geological map; collusions derived from the Pongola supergroup according to simplified and updated geological map of SA (rocks aging about 3 billions of years).
Bedrock consisting in more or less arkosic metamorphosed sandstone, shale, quartzite veins and, locally (extreme W of the farm), intrusions of dolerite according to personnel observations, but consisting in Karoo dolerite, Dykwa tillite and lower Ecca shale according to map of soil groups of the Zululand, 1/6 000, 1970(?)

ANNEX 3: Soil sampling data

1. Mount Edgecombe, field 41

Soil sampling for humidity measurement after completing the infiltration (on replicates 1 & 2)
Depths: 0-20, 30-40, 60-70 & 90-100 cm
Date of infiltration measurement: 28 Mai 2008
Date of first sampling for moisture by auger: t0 (=3 h after end infiltration), t2 (two days after end infiltration) and t3 (5 days after infiltration)
Depth of infiltration: >115 cm in R1, about 105 cm in R2.
Total amount of water applied: 30 cm in R1, 32 in R2, & 50 cm in R3
Soil moisture state before infiltration measurement: Topsoil: dry; subsoil: almost dry
Date of soil profil photos: 4 June.
Sampling for bulk density (2 x 250 cc) *and for RAW + Bd values* (3 replicates of 100 cc) at 0-5, 30-35, 60-65 & ± 95 cm
Bulk sampling[32]*:* 0-5, 10-20, 25-45, 60-70 & 90-110 cm

2. Mount Edgecombe, field 23, sector South

Soil sampling for humidity measurement after completing the infiltration (on replicates 1 & 3)
Depths: 0-15, 25-35, 60-70 & 90-100 cm
Date of infiltration measurement: 29 Mai 2008
Date of first sampling for moisture by auger: (t0) =3 h after completing infiltration; date of second sampling 2 June = j4
Depth of infiltration :> 105 cm in replicate 1, 100 cm in replicate 3
Total amount of water applied: 45 in R1, 32-35 in R2 & 55-58 cm in R3
Soil moisture state before infiltration measurement: Topsoil: dry; subsoil: almost dry
Date of soil profil photos : 30 Mai
Sampling for bulk density (2 x 250 cc) *and for RAW + Bd values* (3 replicates of 100 cc) at 0-5, 15-20, 50-55 & 90-95 cm
Bulk sampling: 0-5, 10-20, 30-40, 50-60, 70-80 & 90-110 cm

3. Mount Edgecombe, field 23, sector North

Soil sampling for humidity measurement after completing the infiltration (on replicates 2 & 3)
Depths: 0-20, 30-40 & 60-70 cm
Date of infiltration measurement: 30 Mai 2008
Date of first sampling for moisture by auger: (t0) =3 h after completing infiltration; date of second sampling 2 June (= j3)
Total amount of water applied: 30 in R1, 50 in R2 & 32 cm in R3
Soil moisture state before infiltration measurement: Topsoil: dry; subsoil: almost dry
No sampling for Bulk density ande for RAW & Bd measurements on rings
Bulk sampling: 0-5, 10-20, 30-40 & 60- 70cm

4. La Mercy

Soil sampling for humidity measurement after completing the infiltration (on replicate 1 & 2))

[32] Bulk samples are compound samples in this study because they were obtained by sampling on 3 sites of the soil pit at the indicated depth level.

Depths: 0-20, 30-40, 50-70 & 100-110cm
Date of infiltration measurement: 7 July 2008
Date of first sampling for moisture by auger: (t0) =2 h after completing infiltration; date of second sampling 10 July (= j3)
Depth of infiltration: about 100 cm, (diffuse wetting front for the two augerings)
Total amount of water applied: 30 cm in all replications
Soil moisture state before infiltration measurement: dry; also sampled at depths 0-20, 30-40, 50-70 & 100-110cm
Sampling for bulk density (2 x 250 cc) *and for RAW + Bd values* (3 replicates of 100 cc) at 5-10, 30-35 & 60-65 cm
Bulk sampling: 0-20, 20-40, 55-75 & 100-120 cm

5. Bruynshill farm, field 6A

Soil sampling for humidity measurement after completing the infiltration (on replicate 1 & 3)
Depths: 0-15/20, 30-40, 50-70 & 100-120 cm
Date of infiltration measurement: June 2008
Date of first sampling for moisture by auger: (t0) =2 h after completing infiltration; date of second sampling June (= j3)
Depth of infiltration: front not clearly detected
Total amount of water applied: 15 to 20 cm in the replications
Soil moisture state before infiltration measurement: slightly humid in top layer, humid below and dry in deep subsoil. Also sampled at depths 0-15/20, 30-40, 50-70 & 100-120 cm
Sampling for bulk density (2 x 250 cc) *and for RAW + Bd values* (3 replicates of 100 cc) at 10-15, 32-37, 60-65 & 125-130 cm
Bulk sampling: 0-20, 30-40, 50-70 & 115-130 cm

6. Pongola farm, field 316

Soil sampling for humidity measurement after completing the infiltration (on replicate 1 & 3)
Depths: 0-15, 20-30, 45-60 & 80-100cm
Date of infiltration measurement: 17 June 2008
Date of first sampling for moisture by auger: (t0) =2 h after completing infiltration; date of second sampling 20 June (= j3)
Depth of infiltration: 90 cm in replicate 1, 95cm in replicate 3
Total amount of water applied: 25 cm in all replications
Soil moisture state before infiltration measurement: slightly humid in top layer, humid below and dry in deep subsoil. Also sampled at depths 0-15, 20-30, 45-60 & 80-100cm
Sampling for bulk density (2 x 250 cc) *and for RAW + Bd values* (3 replicates of 100 cc) at 5-10, 23-28, 55-60 & 90-95 cm
Bulk sampling: 0-15, 20-35, 45-75 & 80-110 cm

Remark: Compound bulk samples of the level 0-20 and 45-65 cm were also taken in field 306 which has a similar soil as the one described and sampled in field 318. The compound samples were made up from 15 augerings done along the axe of the field

ANNEX 4: Infiltration trials data

(double ring falling head method; diameter inner ring ± 30 cm, diameter outer ring ± 60 cm)

1. Mount Edgecombe, field 41, date: 28/05/2008

GPS: 29°42.440'S, 31°03.015'E, 97 m asl
Soil taxonomy SA: Tukulu soil form on Precambrian shale
Observation: Measurements done in trashed 'break'
Summary of the results:
Estimated Vi from the 3 tests
Vi in very topsoil (very porous) ± 40 cm/h = very high
in bottom of A: 15 to 25 cm/h
in subsoil (neocutanic) and deeper (96-90- 55) = ± 8 cm/h

Repl.1
Soil moisture state immediately before the measurement: dry
Pre-watering, day before: 0 Immediately before start of the lectures: 5

lectures and calculations

Hour h.min.sec	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
8. 55.30	45		0		0		200
8.57.30	58		2	2	13	390	187
8.59.30	69		2	4	11	330	176
9.03	83	93 ?	3.5	7.5	14	240	162
9.05	99		2	9.5	16	480	146
9.08	111		3	12.5	12	240	134
9.11	122		3	15.5	11	220	123
9.14	133		3	18.5	11	220	112
9.18	149		4	22.5	16	240	96
9.22	161		4	26.5	12	180	84
9.27	170	? = 180	5	31.5	9	108	75
9.37	199		10	41.5	29	174	46
9.47	222		10	51.5	23	138	23
9.57	245	end	10	61.5	23	138	0
total amount of water applied: 5+5+20 = 30 cm							
2th water application							
10.02	44		0	66.5	0		211
10.12	70		10	76.5	26	156	185
10.22	93		10	86.5	23	138	162
10.32	111		10	96.5	18	108	144
10.42	128		10	106.5	17	102	127
10.52	144		10	116.5	16	96	111
11.02	161		10	126.5	17	102	94
11.12	173		10	136.5	12	72	82
11.22	185		10	146.5	12	72	70
11.32	194		10	156.5	9	54	61
11.42	203		10	166.5	9	54	52
11.52	213		10	176.5	10	60	42
12.02	222	stays 3 cm	10	186.5	9	54	33

total amount of water applied: 30 + 25 = 55 cm
Wetting front >115 cm

Repl.2

Soil moisture state immediately before the measurement: dry

Pre-watering, day before: 0 Immediately before start of the lectures: 5

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
	lectures and calculations						
9.20	0		0	0	0		250
9.22	9		2	2	9	270	241
9.27	19	29?	5	7	10	120	231
9.37	67		10	17	48	288	183
9.47	95		10	27	28	168	155
9.57	120		10	37	25	150	130
10.07	145		10	47	25	150	105
10.17	165		10	57	20	120	85
10.27	185		10	67	20	120	65
10.37	199		10	77	14	84	51
10.47	216		10	87	17	102	34
10.57	230		10	97	14	84	20
11.07	245		10	107	15	90	5

Total amount of applied water : 5+2+25 = 32 cm

Wetting front at 105 cm

Repl.3

Soil moisture state immediately before the measurement: dry

Pre-watering, day before: 0 Immediately before start of the lectures: 5

observations: V in inner ring < V outer ring

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)	Z cumul
	lectures and calculations							
9.36	99			0	0		231	0
9.39	123		3	3	24	480	207	24
9.42	143		3	6	20	400	187	44
9.45	163		3	9	20	400	167	64
9.48	184		3	12	21	420	146	85
9.51	199		3	15	15	300	131	100
9.56	222		5	20	23	276	108	123
10.03	252		7	27	30	257	78	153
10.08	272		5	32	20	240	58	173
10.13	289		5	37	17	204	41	190
10.18	303		5	42	14	168	27	204
10.23	319		5	47	16	192	11	220
total amount of water applied before refilling: 5+2+22=30 cm								
10.27	97		0	0	0		233	
10.32	119		5	5	22	264	211	
10.37	139		5	10	20	240	191	
10.43	160	? For time	6	16	21	210	170	
10.48	186		5	21	26	312	144	
10.53	199		5	26	13	156	131	
10.58	214		5	31	15	180	116	
11.03.30'	232		5.5	36.5	18	196	98	

11.08	244	4.5	41	12	160	86
11.14	259	4	45	15	225	71
11.18	267	5	50	8	96	63
11.23	278	5	55	11	132	52
11.29	287	5	60	9	108	43
11.33	295	5	65	8	96	35
11.43	311	10	75	16	96	19
11.53	327	10	85	16	96	3

Total amount of water applied =30+2+23= 55 cm

2. Mount Edgecombe field 23, South, date: 29/05/2008

Soil type SA taxonomy: Arcadia soil form with lithocutanic "B' on dolerite
Obsevation: Measurements in absence of trash; structural surface state.
Summary of the results:
Estimated Vi from the 3 replications
very topsoil (very poreous): (128 -120-76=) 105 ± 25 cm/h
B' horizon: (38-22- 5=) 22 ± 16 cm/h

Repl.1

Soil moisture state immediately before the measurement: dry, slightly fresh in subsoil
Estimated cm of water applied and infiltrated before start of the infiltration rate measurement
Pre-watering, day before: 7 Immediately before start of the lectures: 3
observations: V int < Vext

lectures and calculations

Hour	Water level	observations	Δ time	time since	Δ Z	V instant	Depth water
h.min.sec	Z (in mm)		min	start (min)		mm/h	(mm)
7.15	70		0	0	0		200
7.16	90		1	1	20	1200	180
7.17	106		1	2	16	960	164
7.18	140	?	1	3	34	2040	130
7.19	163		1	4	23	1380	107
7.20	182		1	5	19	1140	88
7.21	200		1	6	18	1080	70
7.22	219		1	7	19	1140	51
7.23	233		1	8	14	840	37
7.24	249		1	9	16	960	21
7.25	262		1	10	13	780	8
7.26		EMPTY	TOTAL AMOUNT OF WATER APPLIED:28 CM				
refilling							
8.25	63		0	70	0		200
8.27	99		2	72	36	1080	164
8.29	102	?	2	74	3	90	161
8.31	132	?	2	76	30	900	131
8.33	161		2	78	29	870	102
8.35	178		2	80	17	510	85
8.37	195		2	82	17	510	68
8.40	220		3	85	25	500	43
8.42	232		2	87	12	360	31
8.44	245		2	89	13	390	18
8.46	258		2	91	13	390	5
8.48		EMPTY					

TOTAL AMOUNT OF WATER APPLIED:48 cm

Repl.2

Soil moisture state immediately before the V measurement: dry, slightly fresh in subsoil
Estimated cm of water applied and infiltrated before start of the infiltration rate measurement
Pre-watering, day before: 7 Immediately before start of the lectures: 3
observations:

<u>*lectures and calculations*</u>

Hour	Water level	observations	Δ time	time since	Δ Z	V instant	Depth water
h.min.sec	Z (in mm)		min	start (min)		mm/h	(mm)
7.32	55			0			190
7.33	75		1	1	20	1200	170
7.34	94		1	2	19	1140	151
7.35	110		1	3	16	960	135
7.36	124		1	4	14	840	121
7.37	138		1	5	14	840	107
7.38	152		1	6	14	840	93
7.39	165		1	7	13	780	80
7.40	176		1	8	11	660	69
7.41	187		1	9	11	660	58
7.42	197		1	10	10	600	48
7.43	207		1	11	10	600	38
7.44	217		1	12	10	600	28
7.45	226		1	13	9	540	19
7.46	234		1	14	8	480	11
7.47	243		1	15	9	540	2
EMPTY	TOTAL AMOUNT OF WATER APPLIED:29 CM						
9.00	55			78			200
9.02	76		2	80	21	630	179
9.04	93		2	82	17	510	162
9.06	108		2	84	15	450	147
9.08	122		2	86	14	420	133
9.10	135		2	88	13	390	120
9.12	147		2	90	12	360	108
9.14	157		2	92	10	300	98
9.16	169		2	94	12	360	86
9.18	179		2	96	10	300	76
9.20	189		2	98	10	300	66
9.22	198		2	100	9	270	57
9.24	206		2	102	8	240	49
9.26	215		2	104	9	270	40
9.28	222		2	106	7	210	33
9.30	230		2	108	8	240	25
9.32	236		2	110	6	180	19
9.34	244		2	112	8	240	11
9.36	251		2	114	7	210	4

TOTAL AMOUNT OF WATER APPLIED:50 cm

Repl.3

Soil moisture state immediately before the V measurement: dry, slightly fresh in subsoil
Estimated cm of water applied and infiltrated before start of the infiltration rate measurement
Pre-watering, day before: 7 Immediately before start of the lectures: 3

<u>*lectures and calculations*</u>

Hour	Water level	observations	Δ time	time since	Δ Z	V instant	Depth

h.min.sec	Z (in mm)	min	start (min)		mm/h	water (mm)
7.51	109		0	0		210
7.52	120	1	1	11	660	199
7.53	135	1	2	15	900	184
7.54	147	1	3	12	720	172
7.55	156	1	4	9	540	163
7.56	165	1	5	9	540	154
7.57	175	1	6	10	600	144
7.58	185	1	7	10	600	134
7.59	195	1	8	10	600	124
8.00	204	1	9	9	540	115
8.01	212	1	10	8	480	107
8.03	229	2	12	17	510	90
8.05	244	2	14	15	450	75
8.07	259	2	16	15	450	60
8.09	275	2	18	16	480	44
8.11	289	2	20	14	420	30
8.13	302	2	22	13	390	17
8.15	314	2	24	12	360	5
EMPTY	TOTAL AMOUNT OF WATER APPLIED:31 CM					
9.39	111	0	108	0		215
9.41	123	2	110	12	360	203
9.43	135	2	112	12	360	191
9.45	146	2	114	11	330	180
9.47	156	2	116	10	300	170
9.49	164	2	118	8	240	162
9.51	172	2	120	8	240	154
9.53	181	2	122	9	270	145
9.55	186	2	124	5	150	140
9.58	196	3	127	10	200	130
10.02	208	4	131	12	180	118
10.06	220	4	135	12	180	106
10.10	231	4	139	11	165	95
10.15	243	5	144	12	144	83
10.20	250	5	149	7	84	76
10.25	258	5	154	8	96	68
10.30	267	5	159	9	108	59
10.40	281	10	169	14	84	45
10.50	293	10	179	12	72	33
11.00	303	10	189	10	60	23
11.10	311	10	199	8	48	15
11.20	320	10	209	9	54	6
TOTAL AMOUNT OF WATER APPLIED:53 CM						

3. Mount Edgecombe, field 23 North, date: 30/05/2008

Soil type SA taxonomy: Mayo soil form with lithocutanic "B' on dolerite
Obsevation: Measurements in absence of trash
Summary of the results:
Estimated Vi from the 3 replications
very topsoil (very poreous): 60 ± 10 cm/h = very high
B' horizon: (17.5-10.5 -13.5=) 14 ± 3 cm/h = high

Repl.1

Soil moisture state immediately before the V measurement: dry, slightly fresh in subsoil
Estimated cm of water applied and infiltrated before start of the infiltration rate measurement
Pre-watering, day before: 5 Immediately before start of the lectures: 3
observations: V int < Vext

lectures and calculations

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
7.38	54		0	0	0		221
7.40	73		2	2	19	570	202
7.42	84		2	4	11	330	191
7.44	93		2	6	9	270	182
7.47	108		3	9	15	300	167
7.50	122		3	12	14	280	153
7.53	134		3	15	12	240	141
7.56	145		3	18	11	220	130
8.00	160		4	22	15	225	115
8.04	172		4	26	12	180	103
8.08	182		4	30	10	150	93
8.12	192		6	36	10	100	83
8.18	205		6	42	13	130	70
8.24	221		6	48	16	160	54
8.30	234		6	54	13	130	41
8.36	248		6	60	14	140	27
8.42	262		6	66	14	140	13
8.48	272	?	6	72	10	100	3

total amount of water applied: 30 cm
depth wetting front > 70 cm

Repl.2

Soil moisture state immediately before the V measurement: dry, slightly fresh in subsoil
Estimated cm of water applied and infiltrated before start of the infiltration rate measurement
Pre-watering, day before: 5 Immediately before start of the lectures: 3
observations: V int<V ext during 1th filling V int > V ext

lectures and calculations

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
7.59	61		0	0			220
8.00	76		1	1	15	900	205
8.01	87		1	2	11	660	194
8.02	97		1	3	10	600	184
8.03	109		1	4	12	720	172
8.04	120		1	5	11	660	161
8.06	139		2	7	19	570	142
8.08	156		2	9	17	510	125

8.10	174		2	11	18	540	107
8.12	192		2	13	18	540	89
8.14	203		2	15	11	330	78
8.16	216		2	17	13	390	65
8.18	230		2	19	14	420	51
8.21	250		3	22	20	400	31
8.24	264		3	25	14	280	17
8.27	279		3	28	15	300	2

EMPTY AND REFILL.; TOTAL AMOUNT OF WATER APPLIED:30 CM

9.00	47						230
9.04	69		4	31	22	330	208
9.08	94		4	35	25	375	183
9.12	102		4	39	8	120	175
9.14?	108	?	6	45	6	60	169
9.24	143		10	55	35	210	134
9.34	173		10	65	30	180	104
9.44	198		10	75	25	150	79
9.54	221		10	85	23	138	56
10.04	232	? FOR Z	10	95	11	66	45
10.14	259		10	105	27	162	18
10.24	274		10	115	15	90	3

totol amount of water applied: 30 + 20 = 50 cm

Repl.3

Soil moisture state immediately before the V measurement: dry, slightly fresh in subsoil
Estimated cm of water applied and infiltrated before start of the infiltration rate measurement (V):
Pre-watering, day before: 5 Immediately before start of the lectures: 3
observations: surface of soil dispersed at end essai

<u>*lectures and calculations*</u>

Hour h.min.sec	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
8.34	105		0	0	0		235
8.35	117		1	1	12	720	223
8.36	127		1	2	10	600	213
8.37	137		1	3	10	600	203
8.39	156		2	5	19	570	184
8.41	173		2	7	17	510	167
8.43	188		2	9	15	450	152
8.45	202		2	11	14	420	138
8.47	215		2	13	13	390	125
8.50.30	235		3.5	16.5	20	343	105
8.53	248		3	19.5	13	260	92
8.56	262		3	22.5	14	280	78
8.59	274		3	25.5	12	240	66
9.02	286		3	28.5	12	240	54
9.05	299		3	31.5	13	260	41
9.08	312		3	34.5	13	260	28
9.12	322		4	38.5	10	150	18
9.16	334		4	42.5	12	180	6

total water amount aplied:24+5+3= 32 cm

4. La Mercy (Tongaat-Hulett), field 13221, (previous 200), date: 07/07/2008

GPS: 29°36.971'S, 31°05.226'E, 99 m asl
Soil taxonomy SA: Swartland soil form (Orthic A, pedocutanic B on saprolite)
Summary of the results:
Estimated steady Vi from the 3 tests
very topsoil : 20 to 30 cm/h
subsoil :going progressively down to 5-6 cm/h below 70 cm depth

Repl.1
Soil moisture state immediately before the measurement: dry
Estimated cm of water applied & infiltrated before start of the infiltration rate measurement: 5 cm
Pre-watering, day before: 0 Immediately before start of the lectures: 4
observations: diffuse wetting front at about 100 cm 2h after end of the test

<u>*lectures and calculations*</u>

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
8.30	21			0			262
8.33	38		3	3	17	340	245
8.36	60	error in minute	3	6	22	440	223
8.39	76		3	9	16	320	207
8.42	91		3	12	15	300	192
8.45	106		3	15	15	300	177
8.48	120		3	18	14	280	163
8.51	132		3	21	12	240	151
8.54	144		3	24	12	240	139
8.57	156		3	27	12	240	127
9.00	167		3	30	11	220	116
9.03	176		3	33	9	180	107
9.09	195		6	39	19	190	88
9.15	212		6	45	17	170	71
9.21	229		6	51	17	170	54
9.27	244		6	57	15	150	39
9.33	255		6	63	11	110	28
9.39	267		6	69	12	120	16
9.45	EMPTY AT 283 mm						

Repl.2
Soil moisture state immediately before the V measurement: dry
Estimated cm of water applied & infiltrated before start of the infiltration rate measurement: 5 cm
Pre-watering, day before: 0 Immediately before start of the lectures: 4
observations: diffuse wetting front at about 100 cm 2h after end of the test

<u>*lectures and calculations*</u>

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
8.33	18						270
8.36	31		3	3	13	260	257
8.39	40		3	6	9	180	248
8.44	55		5	11	15	180	233
8.48	65		4	15	10	150	223

8.52	75		4	19	10	150	213
8.56	85		4	23	10	150	203
9.00	95		4	27	10	150	193
9.04	105		4	31	10	150	183
9.08	114		4	35	9	135	174
9.14	125		6	41	11	110	163
9.20	137		6	47	12	120	151
9.26	148		6	53	11	110	140
9.32	159		6	59	11	110	129
9.38	168		6	65	9	90	120
9.44	177		6	71	9	90	111
9.50	186		6	77	9	90	102
9.56	195		6	83	9	90	93
10.02	203		6	89	8	80	85
10.12	215		10	99	12	72	73
10.22	225		10	109	10	60	63
10.32	236		10	119	11	66	52
10.42	246		10	129	10	60	42
10.52	255	STAYS 3 CM	10	139	9	54	33

Repl.3

Soil moisture state immediately before the V measurement: dry

Estimated cm of water applied & infiltrated before start of the infiltration rate measurement: 5 cm

Pre-watering, day before: 0 Immediately before start of the lectures: 4

lectures and calculations

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
8.35	9						265
8.39	22		4	4	13	195	252
8.43	34		4	8	12	180	240
8.47	45		4	12	11	165	229
8.51	55		4	16	10	150	219
8.55	64		4	20	9	135	210
9.01	77		6	26	13	130	197
9.07	90		6	32	13	130	184
9.13	101		6	38	11	110	173
9.19	112		6	44	11	110	162
9.25	122		6	50	10	100	152
9.31	131		6	56	9	90	143
9.37	140		6	62	9	90	134
9.43	149		6	68	9	90	125
9.49	157		6	74	8	80	117
9.55	166		6	80	9	90	108
10.01	173		6	86	7	70	101
10.11	186		10	96	13	78	88
10.21	197		10	106	11	66	77
10.31	207		10	116	10	60	67
10.41	216		10	126	9	54	58
10.51	225	STAYS 5 CM	10	136	9	54	49

5. Bruynshill, field 6A, date:9/06/2008

GPS: 29°25'13.445"S, 030°'40'39.660"E, 1015 m asl
Soil taxonomy SA: Inanda soil form, Fontainhill series on (partly arkosic) sandstones or mixted with shale
Soil moisture state immediately before the measurement: slightly humid in top, fresh and then humid in deeper layers
Summary of the results: (Estimated Vi in interow from the 3 tests)
very topsoil : 6.5-11mm/h (6,5 mm/h in compacted sites)
immeditelay below: 6-8 = 7 mm/h
subsoil: according to watering done during ring sampling, the infiltration rate is distincly higher than in topsoil
Question: Origin of the very low hydraulic conductivity of the topsoil ?
(1) soil compaction by mechanized cane stalk loading,
(2) loss in (low) soil biological activity (= very low) and in fresh organic matter input
Pratical consequences:
(1) high risque of runoff and erosion during spells of rain with high intensity
(2) complentary to contour cropping: need to on "ridge" cane growing & trash blankering between the cane rows

Repl. 1

Estimated cm of water applied and infiltrated before start of the infiltration rate measurement (V): 1
Pre-watering, day before: 0 Immediately before start of the lectures: 5
observations: prewatering not totaly infiltrated before filling of the rings

lectures and calculations

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z mm	V instant mm/h	Depth water (mm)	*Δ Z mm*	*Δ time min*	*V instant mm/h*
10.12	40			0			210			
11.02	45		60	60	5	5	205			
11.32	50		30	90	5	10	200	*10*	*90*	*6.7*
12.02	53		30	120	3	6	197			
12.32	57		30	150	4	8	193			
16.04	84	LOCAL	212	362	27	8	166			
7.11	180	LOCAL	907	1269	96	6	70			
10.55	190	Vi<Ve	224	1493	10	3	60	*133*	*1343*	*5.9*
	STAYS 6 cm									

Repl. 2

Estimated cm of water applied and infiltrated before start of the infiltration rate measurement (V): 2
Pre-watering, day before: 0 Immediately before start of the lectures: 5
observations: prewatering not totaly infiltrated before filling of the rings

lectures and calculations

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z mm	V instant mm/h	Depth water (mm)	*Δ Z mm*	*Δ time min*	*V instant mm/h*
10.16	25			0			260			
10.25	30		9	9	5	33	255			
10.37	33		12	21	3	15	252			
11.03	36		26	47	3	7	249			
11.33	43		30	77	7	14	242			
12.03	48	47	30	107	5	10	237			
12.33	53		30	137	5	10	232	23	128	*10.8*
16.04	85	LOCAL	211	348	32	9	200			
7.11	195	LOCAL	907	1255	110	7	90			
10.55	223	Vi<Ve	224	1479	28	8	62	170	1342	*7.6*
	STAYS 6 cm									

Repl. 3

Estimated cm of water applied & infiltrated before start of the infiltration rate measurement: 3

Pre-watering, day before: 0 Immediately before start of the lectures: 5

observations: prewatering not totaly infiltrated before filling of the rings

lectures and calculations

Clock time	Water level	observations	Δ time	time since	Δ Z	V instant	Depth water	*Δ Z*	*Δ time*	*V instant*
h.min.	Z (in mm)		min	start (min)	mm	mm/h	(mm)	*mm*	*min*	*mm/h*
10.21	42			0			240			
11.04	50		43	43	8	11	232			
11.34	53		30	73	3	6	229			
12.04	58		30	103	5	10	224			
12.34	64		30	133	6	12	218	*22*	*133*	*9.9*
16.04	96	LOCAL	210	343	32	9	186			
7.11	196	LOCAL	907	1250	100	7	86			
10.55	216	Vi<Ve	224	1474	20	5	66	*152*	*1341*	*6.8*
	STAYS 6 CM									

6. Pongola, field 318, date 17/06/2008

GPS: 27°24.884'S, 31°35.675'E, 306 m asl
Observations: (1) Infiltration probably quicker in non topsoil levels then those revealed by quick testing during ring sampling
(2) large differences in steady stead infiltration due to the fact that cane loading is done mechanical
(3) important soil biological mainly due to termites (nest in the soil, termites mouths on the surface, most of them destructed at harvest, and by animals)
Summary of the results:
Estimated Vi from the 3 tests
very topsoil (may be porous) : 5-5,5 cm/h in compacted sites to 22 cm/ in not compacted sites
subsoil = 10 to 16 cm/h

Repl.1

Soil moisture state immediately before the V measurement: fresh
Estimated cm of water applied & infiltrated before start of the infiltration rate measurement: 5 cm
Pre-watering, day before: 0 Immediately before start of the lectures: 5
observations: wetting front at 90 cm 2h after end of the test

	lectures and calculations						
Clock time	Water level	observations	Δ time	time since	Δ Z	V instant	Depth water
h.min.	Z (in mm)		min	start (min)		mm/h	(mm)
9.51	26		0	0	0		210
10.02	38		11	11	12	65	198
10.12	46		10	21	8	48	190
10.25	58		13	34	12	55	178
10.38	70		13	47	12	55	166
10.51	82		13	60	12	55	154
11.04	93		13	73	11	51	143
11.17	104		13	86	11	51	132
11.30	115		13	99	11	51	121
	stays 12 cm						

Repl.2

Soil moisture state immediately before the V measurement: fresh
Estimated cm of water applied & infiltrated before start of the infiltration rate measurement: 7 cm
Pre-watering, day before: 0 Immediately before start of the lectures: 5
observations:

	lectures and calculations						
Clock time	Water level	observations	Δ time	time since	Δ Z	V instant	Depth water
h.min.	Z (in mm)		min	start (min)		mm/h	(mm)
8.54	29		0	0	0	0	243
9.57	44		3	3	15	300	228
10.00	55		3	6	11	220	217
10.03	66		3	9	11	220	206
10.06	73		3	12	7	140	199
10.10	85		4	16	12	180	187
10.14	101		4	20	16	240	171
10.18	112		4	24	11	165	160
10.22	123		4	28	11	165	149

10.26	132		4	32	9	135	140
10.30	143		4	36	11	165	129
10.34	155		4	40	12	180	117
10.38	168	?	4	44	13	195	104
10.44	180		6	50	12	120	92
10.50	193		6	56	13	130	79
10.56	207		6	62	14	140	65
11.02	219		6	68	12	120	53
11.09	230	?	7	75	11	94	42
11.14	241		5	80	11	132	31
11.20	252		6	86	11	110	20
11.26	262		6	92	10	100	10
11.32	272		6	98	10	100	0
	no water						

Repl.3

Soil moisture state immediately before the V measurement: fresh
Estimated cm of water applied and infiltrated before start of the infiltration rate measurement: 7 cm
Pre-watering, day before: 0 Immediately before start of the lectures: 5
observations: wetting front at 95 cm 2 H after end infiltration test

lectures and calculations

Clock time h.min.	Water level Z (in mm)	observations	Δ time min	time since start (min)	Δ Z	V instant mm/h	Depth water (mm)
9.56	43	?	0	0	0		210
9.58	54		2	2	11	330	199
10.01	67		3	5	13	260	186
10.05	79		4	9	12	180	174
10.09	94	95?	4	13	15	225	159
10.13	114		4	17	20	300	139
10.17	125		4	21	11	165	128
10.21	141		4	25	16	240	112
10.25	152		4	29	11	165	101
10.29	165		4	33	13	195	88
10.33	180		4	37	15	225	73
10.37	190		4	41	10	150	63
10.43	209		6	47	19	190	44
10.49	225		6	53	16	160	28
10.55	241		6	59	16	160	12
10.57	246		2	61	5	150	7
	no water						

ANNEX 5: Moisture content % by weight between 10 and 1500 kPa of 100 cm3 ring sample (mean of 3 replications)

Site	depth (cm)	10 kPa	33 kPa	100 kPa	1.5 Mpa	DENSITY g/cm³
				(% w/w)		
Mt Edge 41	0-5	20.3	19.4	18.5	15.7	1.51
	30-35	*16.8*	*16.3*	*15.6*	*13.6*	*1.71*
	60-65	19.8	19.3	18.7	17.4	1.66
	± 95	27.6	27.2	26.4	24.8	1.48
Mt Edge 23 S	0-5	34.0	33.3	32.7	27.8	1.26
	15-20	47.6	46.9	45.5	41.7	1.13
	50-55	48.5	46.9	45.5	42.0	1.09
	90-95	40.8	39.1	39.1	36.3	1.24
La Mercy	5 - 10	20.9	20.4	19.8	15.5	1.53
	30 - 35	20.4	19.3	18.7	16.1	1.60
	60 - 65	31.0	30.7	30.3	26.7	1.35
Bruynshill	10-15	25.9	24.9	24.4	19.8	1.36
	32-37	28.2	27.4	27.0	20.2	1.31
	60-65	26.4	25.6	25.4	19.1	1.38
	125-130	29.3	28.4	28.0	21.7	1.35
Pongola	5-10	21.3	20.5	20.5	18.0	1.47
	23-28	*16.6*	*16.1*	*15.6*	*13.1*	*1.73*
	55-60	21.3	20.9	20.1	15.4	1.47
	90-95	22.4	21.9	21.3	15.1	1.51

Data in italique = non relevant due to compaction during sampling

ANNEX 6: Particle size distribution and moisture retention at 1500 kPa

SITE	depth	clay	silt	sand	clay FAS	texture	Moiture at 1500 kPa
	(cm)	(%)	(%)	(%)	(%)	class	(%) w/w
Mt Edge 41	0 - 5 cm	17.8	13.2	69.0	21	*sl*	8
	10 - 20 cm	19.1	11.0	69.9	23	*sl*	11
	25 - 45 cm	22.0	10.6	67.4	25	*scl*	9
	60 - 70 cm	28.3	11.8	59.8	34	*scl*	10
	90 - 110 cm	42.2	16.0	41.8	44	*c*	18
Mt Edge 23 S	0 - 5 cm	58.2	23.3	18.6	50	*c*	26
	10 - 20 cm	58.3	22.1	19.6	50	*c*	29
	30 - 40 cm	68.9	15.3	15.7	61	*c*	32
	50 - 60 cm	64.8	23.5	11.7	59	*c*	39
	70 - 80 cm	31.8	18.1	50.1	27	*scl*	30
	90 - 110 cm	26.6	20.3	53.0	23	*scl*	32
Mt Edge 23 N	0 - 5 cm	37.6	17.3	45.1	36	*sc*	13
	10 - 20 cm	33.0	18.4	48.6	34	*scl*	15
	30 - 40 cm	39.0	15.8	45.2	40	*sc/cl*	28
	60 - 80 cm	17.8	12.7	69.5	21	*sl*	24
La Mercy	0 - 20 cm	27.1	17.9	55.0	23	*scl*	10
	20 - 40 cm	31.1	16.4	52.5	29	*scl*	12
	55 - 75 cm	57.5	15.4	27.1	55	*c*	22
	100 - 120 cm	53.0	14.9	32.1	49	*c*	22
Bruynshill	0 - 20 cm	28.5	10.2	61.3	34	*scl*	14
	30 - 40 cm	31.5	11.5	57.0	34	*scl*	13
	50 - 70 cm	35.1	10.7	54.2	38	*scl/sc*	12
	110 - 130 cm	43.2	9.3	47.5	42	*sc*	14
Pongola	0 - 15 cm	20.1	12.8	67.1	23	*sl/scl*	14
	20 - 35 cm	34.5	10.5	54.9	36	*scl/sc*	12
	45 - 65 cm	36.9	12.2	50.9	36	*sc*	12
	80 - 110 cm	35.2	12.3	52.4	34	*sc/scl*	12
Pong 306	0 - 20 cm	24.7	10.8	64.4	19	*scl*	13
	45 - 65 cm	38.9	10.6	50.5	38	*sc*	25

Clay, silt and sand % as determined by SASRI's soil physics laboratory
Clay FAS = estimated clay % by FAS according a NIRS method
Texture class: according to results of soil physics laboratory & international textural classes chart

ANNEX 7: pH, CEC and exchangeable cations

SITE	depth (cm)	pH water	Exchangeable cations cmol.kg-1 Ca	Mg	K	Na	Al	Σ	KSAR %	Σ/Clay cmol.kg-1
Mt Edge 41	0 - 5	5.62	3.31	1.15	0.15	0.11		*4.72*	*5.61*	*26.44*
	10 - 20	6.05	4.35	1.16	0.08	0.13		*5.72*	*3.73*	*29.96*
	25 - 45	6.55	5.25	1.06	0.07	0.15		*6.53*	*3.46*	*29.71*
	60 - 70	6.73	4.39	1.13	0.06	0.17		*5.75*	*3.92*	*20.30*
	90 - 110	6.83	4.52	3.37	0.09	0.21		*8.19*	*3.65*	*19.40*
Mt Edge 23 S	0 - 5	5.51	11.83	7.40	0.39	0.25		*19.86*	*3.21*	*34.15*
	10 - 20	5.57	13.02	8.06	0.25	0.34		*21.67*	*2.73*	*37.19*
	30 - 40	6.90	15.57	11.68	0.32	0.42		*28.00*	*2.68*	*40.61*
	50 - 60	7.74	24.50	13.65	0.34	0.44		*38.93*	*2.00*	*60.06*
	70 - 80	7.91	27.50	14.31	0.29	0.42		*42.52*	*1.68*	*133.76*
	90 - 110	7.75	23.85	16.20	0.25	0.49		*40.80*	*1.83*	*153.18*
Mt Edge 23 N	0 - 5	5.50	6.18	4.85	0.29	0.22		*11.54*	*4.37*	*30.71*
	10 - 20	5.98	6.10	5.10	0.19	0.27		*11.66*	*3.95*	*35.34*
	30 - 40	6.88	11.43	11.02	0.31	0.80		*23.55*	*4.68*	*60.37*
	60 - 80	8.30	18.76	18.09	0.26	2.03		*39.15*	*5.85*	*219.96*
La Mercy	0 - 20	4.97	1.71	0.88	0.26	0.10	0.02	*2.97*	*12.15*	*10.97*
	20 - 40	5.71	3.79	1.82	0.10	0.18		*5.90*	*4.77*	*18.96*
	55 - 75	6.13	3.99	6.91	0.13	0.31		*11.34*	*3.96*	*19.73*
	100 - 120	6.77	2.88	9.29	0.16	0.39		*12.73*	*4.36*	*24.02*
Bruynshill	0 - 20	4.90	0.97	0.62	0.33	0.07	0.11	*2.10*	*19.02*	*7.36*
	30 - 40	4.92	1.86	0.26	0.07	0.07	0.02	*2.29*	*6.38*	*7.28*
	50 - 70	4.78	1.24	0.11	0.06	0.10	0.06	*1.58*	*9.86*	*4.49*
	110 - 130	5.05	2.42	0.18	0.04	0.06	0.00	*2.71*	*3.89*	*6.26*
Pongola	0 - 15	6.53	3.42	2.40	0.60	0.07		*6.49*	*10.29*	*32.30*
	20 - 35	6.50	3.42	2.83	0.14	0.17		*6.57*	*4.74*	*19.01*
	45 - 65	6.50	2.79	3.70	0.14	0.18		*6.81*	*4.59*	*18.45*
	80 - 110	6.44	2.34	3.87	0.11	0.15		*6.47*	*4.05*	*18.36*
Pong 306	0 - 20	6.26	3.22	2.39	0.22	0.17		*5.99*	*6.43*	*24.23*
	45 - 65	5.88	2.78	2.32	0.14	0.19		*5.43*	*6.06*	*13.96*

ANNEX 8 : Organic matter, nitrogen and phosphorus

SITE	depth (cm)	Tot. C (%)	*Tot. OM (%)*	OME (%)	C/N	Tot N (ppm)	N Cat	NH3 (%)	NH4 (ppm)	NO3 (ppm)	*N min tot (ppm)*	P Truog (ppm)
Mt Edge 41	0 - 5 cm	1.14	*1.96*	1.86	*13.4*	850	2	1.66	6	9	*15*	14.0
	10 - 20 cm	1.95	*3.35*	1.34	***30.0***	650	2	3.06	8	5	*13*	6.6
	25 - 45 cm	0.87	*1.50*	1.55	*14.5*	600	2	5.55	10	7	*17*	5.0
	60 - 70 cm	0.54	*0.93*	0.93	*12.0*	450	2	5.44	6	3	*9*	4.3
	90 - 110 cm	0.42	*0.72*	0.72	*10.5*	400	2	3.18	2	7	*9*	9.0
Mt Edge 23 S	0 - 5 cm	2.73	*4.70*	3.00	*23.7*	1150	2	0.15	8	5	*13*	21.4
	10 - 20 cm	2.13	*3.66*	3.42	*19.4*	1100	3	0.13	8	5	*13*	12.2
	30 - 40 cm	0.96	*1.65*	1.55	*16.0*	600	2	0.81	4	7	*11*	0.5
	50 - 60 cm	0.75	*1.29*	0.83	*13.6*	550	2	1.33	6	3	*9*	1.6
	70 - 80 cm	0.45	*0.77*	0.25	*18.0*	250	2	1.36	2	3	*5*	1.4
	90 - 110 cm	0.24	*0.41*	0.21	*16.0*	150	2	1.36	6	7	*13*	3.8
Mt Edge 23 N	0 - 5 cm	1.68	*2.89*	2.07	*16.8*	1000	2	0.27	12	5	*17*	12.6
	10 - 20 cm	1.56	*2.68*	1.69	*14.2*	1100	2	0.55	8	11	*19*	6.3
	30 - 40 cm	0.84	*1.44*	2.32	*12.0*	700	2	0.83	4	5	*9*	24.1
	60 - 80 cm	0.15	*0.26*	0.17	*6.0*	250	2	3.00	2	3	*5*	74.1
La Mercy	0 - 20 cm	1.11	*1.91*	0.55	*15.9*	700	2	0.45	4	3	*7*	28.2
	20 - 40 cm	0.87	*1.50*	2.22	*15.8*	550	2	0.76	4	9	*13*	3.6
	55 - 75 cm	1.05	*1.81*	1.45	*23.3*	450	2	0.83	6	9	*15*	3.8
	100 - 120 cm	1.20	*2.06*	0.52	***40.0***	300	2	2.26	4	11	*15*	5.9
Bruynshill	0 - 20 cm	1.77	*3.04*	4.70	*15.4*	1150	3	0.25	10	7	*17*	73.0
	30 - 40 cm	1.65	*2.84*	5.64	*18.3*	900	3	0.25	6	7	*13*	18.0
	50 - 70 cm	1.62	*2.79*	2.48	*23.1*	700	2	0.31	10	7	*17*	2.7
	110 - 130 cm	0.72	*1.24*	0.83	*20.6*	350	2	0.65	10	9	*19*	2.9
Pongola	0 - 15 cm	0.99	*1.70*	0.87	*16.5*	600	2	4.74	8	11	*19*	27.0
	20 - 35 cm	0.51	*0.88*	0.72	*10.2*	500	2	3.06	8	5	*13*	8.6
	45 - 65 cm	0.48	*0.83*	0.41	*12.0*	400	2	1.88	8	11	*19*	5.2
	80 - 110 cm	0.06	*0.10*	0.41	*2.0*	300	2	3.81	8	7	*15*	5.2
Pong 306	0 - 20 cm	0.84	*1.44*	1.26	*8.0*	1050	2	2.50	8	9	*17*	15.1
	45 - 65 cm	0.15	*0.26*	0.31	*3.8*	400	2	2.04	12	7	*19*	0.9

Data of C and C/N in red = surprising values because out of normal range

Data of available P : in red = deficiency, in blue = convenient

OME % = estimation of the % of organic matter by FAS according to a NIRS method

N category & NH3 according to standard FAS methods

Data in italique are calculated